Proposition of a PLM tool to support textile design: A case study applied to the definition of the early stages of design requirements

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ABSTRACT

The current climate of economic competition forces businesses to adapt more than ever to the expectations of their customers. Faced with new challenges, practices in textile design have evolved in order to be able to manage projects in new work environments. After presenting a state of the art overview of collaborative tools used in product design and making functional comparison between PLM solutions, our paper proposes a case study for the development and testing of a collaborative platform in the textile industry, focusing on the definition of early stages of design needs. The scientific contributions presented in this paper are a state of the art of current PLM solutions and their application in the field of textile design; and a case study where we will present, define, and test the mock-up of a collaborative tool to assist the early stages, based on identified intermediary representations.

1. Introduction

Industries today must face the stakes related to the increasing complexity of their work environment and activities: globalization of their markets, increasing distance between industrial partners, pressures related to costs, proliferation of information, evolutions in the environment, reduced time to market, emergence of codesigning practices involving suppliers. This has gradually led to business process outsourcing, one of the most important changes in design practices in the 2000 decade, experienced by many different professions [1].

PLM (Product Lifecycle Management) is both a company strategy and a specialized information system. It unites the various data and processes related to the product, allowing the various types of professionals involved to share this information within collaborative environments.

Functionalities afforded by PLM tools [2] generally include managing technical data, and managing configurations and tools in distributed collaborative design. Fig. 1 illustrates current evolutions in the constitution of product development teams. These tend to be increasingly collaborative and virtualized.

Indeed, the main existing PLM solutions were designed by 3D CAD software firms, and are therefore used very often in the stages of detailed design of a product. In the early stages of design, these solutions are not very flexible and prove to be unsuitable. Furthermore, the textile industry relies heavily on the use of 2D patterns, and Digital Mock-Ups (DMUs) are not very strongly developed. Despite the fact that editors of PLM solutions tend to propose increasingly evolved software programs, at the time of writing, there exists no clear methodology to define a collaborative tool that is suited to the needs of the textile industry.

The scientific contributions of this paper are: (a) a state of the art of current PLM solutions and their application in the textile industry, (b) the presentation of a case study from the textile industry where we identified the main Intermediary Representations (IRs) used by designers, that are most likely to support collaboration; and (c) the definition and testing of a mockup of a collaborative tool to assist the early stages of design and relying on the IRs mentioned above.

We will first present existing PLM tools as well as their main functionalities. We will then describe a case study in the Devanlay textile company, starting with the analysis of requirements in terms of collaborative tools, up to the specification and testing of a collaborative tool. Our conclusion will focus on the generalizability of the method and of the results obtained.

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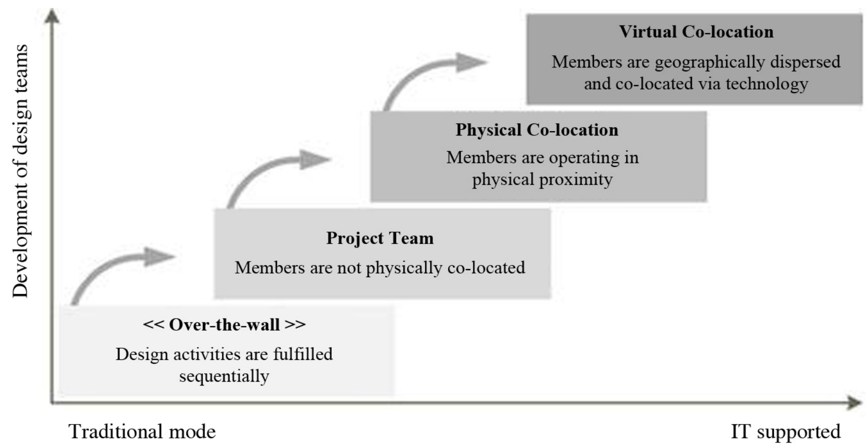

Fig. 1. Evolutions in design teams adapted from [3].

2. PLM and its implementation in the industry

2.1. The evolution of work practices in product design

In this part, we propose a chronological state of the art of the methods applied in the business world in order to improve their competitiveness. These methods, applied in the industrial world, seem to be at the heart of the issue of reducing product development time, which many businesses in the textile industry currently face.

2.1.1. Concurrent engineering

Towards the end of the 1980s and the beginning of the 1990s, two forms of design organization emerged as distinct alternatives: sequential design, which involves carrying out design tasks one after the other, and concurrent engineering, or integrated design [4–6]. Two of the aspects of Concurrent Engineering (CE) that distinguish it from conventional approaches to product development are cross-functional integration and concurrency. In CE, one must define shared interfaces between the various tasks. Indeed, CE is an approach to product development, in which considerations about product lifecycle processes, from product planning, design, production to delivery, service, and even end-of-life, are all integrated. By carrying out all these tasks in a parallel fashion, it becomes possible to reduce the time and costs of design, but also to improve the quality of products. With the development of Information Technology (IT), CE methods have evolved gradually towards PLM.

2.1.2. PLM

In the early 2000s, PLM emerged as a solution to adapt engineering design to the demands of globalization. Indeed, as PLM addresses the entire lifecycle of the product, it has a cross-functional nature and deals closely with the way a company runs [7]. Collaborative design has been the subject of numerous studies. With the development of PDM (Product Data Management), PLM (Product Lifecycle Management) and associated workflows, software firms have proposed solutions to the everyday problems of engineering design departments (versioning of documents, naming etc.). Product Lifecycle Management aims to cover all the stages of product development, by integrating the processes and people taking part in the project [8]. This concept is generally used on industrial products. For Amann [9], over the past several years, PLM has emerged as a term to describe a business approach for the creation, management, and use of product-associated intellectual capital and information throughout the product lifecycle. Thus, PLM is an approach in which processes are just as important as data, or even more so. The PLM approach can be viewed as a trend towards a full integration of all software tools taking part in design and operational activities during a product's lifecycle [7,9]. Therefore, PLM software packages need product data management systems, as well as synchronous and asynchronous, local and remote collaboration tools and if necessary, a digital infrastructure allowing exchanges between software programs.

2.2. Existing PLM solutions and related functionalities

Current PLM tools offer functionalities that can be found in most of software solutions [10]. These can be classified into three main categories: Product Data Management (PDM), configuration management, and distributed design tools.

The main functionalities found in PDM tools are as follows [2]:

- Access rights management: depending on the user's clearance level, (s)he given access to information contained within the PLM system.
- Vaults: datasets and related documents are stored onto a server called a vault, as opposed to being stored locally on the user's computer.
- Document visualization: users are able to rapidly visualize documents in various formats, without owning the application that corresponds to a particular file format.
- Check-out and check-in: this functionality allows users to check out a document in order to ensure that no other user working on the document at the same time may alter it.
- Document versioning: several versions of the same document may be archived.
- States: various states are associated with each document. These help define their level of maturity: creation, validation, obsolescence, etc.
- Workflows: these systems make it possible to model processes and to automate actions. These systems are mostly used in validation processes for documents and technical data.

Configuration management consists in controlling information related to product structure, especially by breaking it down into elementary parts, and adding information related to their functional and physical characteristics [11]. The ISO 10007 standard [12] includes recommendations for using configuration management in the industry. It provides the detailed process, organization and procedures for configuration management. According to this standard, this configuration management is an integral part of PLM. It provides a clear vision of the configuration state associated with a product or project, as well as their evolutions by guaranteeing total traceability [12]. Distributed design tools [13] allow users to share a screen, to remotely gain control over another user's workstation, and to exchange instant messages. They also allow the use of a webcam to visualize a colleague, or of VoIP to talk with him/her.

PLM is currently evolving towards PLM 2.0, which takes advantage of the intelligence that is collectively generated by online communities. In this view, all users may imagine, share, and experiment with 3D products. Current software editors follow a global approach when designing information systems in companies. In other words, such systems aim to structure collaborative work at every stage in the product life cycle; to cater for the needs of every profession involved in the design process, and to make use of all available information and potential sources of innovation. This poses the question of adapting their software to the company's organizational context, as well as the question of the compatibility of information systems within the company. Implementing an integrated information system – or more simply, a shared information system – should never hinder the development of a company [14].

Therefore, the functionalities described in this section must be integrated when choosing and deploying a PLM tool in the specific field of the textile industry. In the section below, we analyze the constraints involved when applying these functionalities to the case of designing a textile product.

2.3. Adapting PLM to textile design

PLM tools are mainly derived from CAD software editors [2]. Therefore the development of PLM in the textile industry closely follows the development of CAD in this sector. However, the use of CAD systems in clothing design is still quite restricted. There are two main reasons for this. First, CAD tools are difficult to access, in financial terms, for businesses whose main investments lie in raw materials. Second, design relies entirely on the use of patterns, which are two-dimensional. These patterns are then assembled to form an item of clothing (see Fig. 2). Since items of clothing are flexible, the types of constraints used in design depend on the pattern makers' experience, and is determined on a case-by-case basis. The well-recognized flowchart of CAD systems for 2D clothing includes the stages of fashion style design, pattern design, pattern grading and marker making [15]. For example, typical commercial CAD software for 2D clothing include Gerber in United States, Shima Seiki in Japan or Lectra and Vetigraph in France.

A further contribution of CAD in textile design is the ability to carry out mechanical simulations in order to verify that the product's specifications are obeyed. These digital simulations have made it possible to drastically reduce development times in industrial product design. They rely on modelling systems, e.g. Finite Element Modelling. In the textile industry, modelling is a far more delicate matter. Consequently, its use is not quite so widespread. Indeed, designing and simulating virtual items of clothing involves combining a wide range of techniques, involving mechanical simulation, collision detection, and user interface techniques, all of which are adapted to the creation of items of clothing [16]. Simulation tools are complex and take advantage of algorithms from the field of mechanical simulation, animation and rendering.

Fig. 2. A 2D-to-3D transformation and simulation model used in the textile industry, adapted from [15] and [16].

Then, in the field of the textile industry, concepts of configuration and traceability are essential. Indeed, each collection numbers roughly 1200 references, and each item of clothing corresponds to a pattern, which is given a specific colour and size, as it is destined for a target customer. Thus, configuring an item of clothing at Devanlay takes into account the following characteristics:

- The item reference
- The colour, size, and design trends
- The product line: knitwear, weft, pullovers, and accessories
- The target market and production platform
- The patterning
- The related bill of material, which takes into account the regulatory constraints of the target market
- Cost and selling prices, which depend on the distribution channel

In the next section, we draw a comparison between the main existing PLM solutions in order to determine their functional capabilities, in a textile application.

2.4. A functional comparison between PLM tools in the textile industry

In order to choose a suitable PLM solution, it is crucial to carry out a technical study of the functionalities present in various available commercial solutions. We have tested, in an industrial context, the ability of various commercial solutions to respond to designer requirements.

These solutions were tested in the field. Our evaluation was based on our use of the various pieces of software tested, running on a dedicated machine, and on our attendance of various technical presentations of these pieces of software. The tests took place over a period of three months, at the head office of a company in Paris. Following the presentation of "industrial" PLM tools by [2], it can be noted that every piece of PLM software cannot easily be adapted for use in the textile industry. Indeed, whereas some software editors focus heavily on PDM, collaborative, and process management functionalities (*e.g.* Dassault Systems and PTC), other editors focus on collaboration and PDM functionalities primarily (Lawson) or, alternately, on textile-specific CAD functionalities (Lectra). Fig. 3 compares various solutions following different criteria.

Following this review, it can be noted that there currently exists no turnkey software solution which would provide all the functionalities expected of a PLM system suited to the textile industry. Consequently, the chosen tools must provide an adequate answer to the analysis of user needs, in the context of multi-user collaborations. Such user needs analysis may rely on interviews with representatives of the software's end-users [17,18]. In the section below, we present the field work we carried out in order to formalize end-user requirements.

2.5. Research questions and methodology

As this state of the art suggests, PLM is one of the major evolutions in the practice of innovation design in recent years and has led to the development and diffusion of numerous software solutions. However, it also suggests that the textile industry

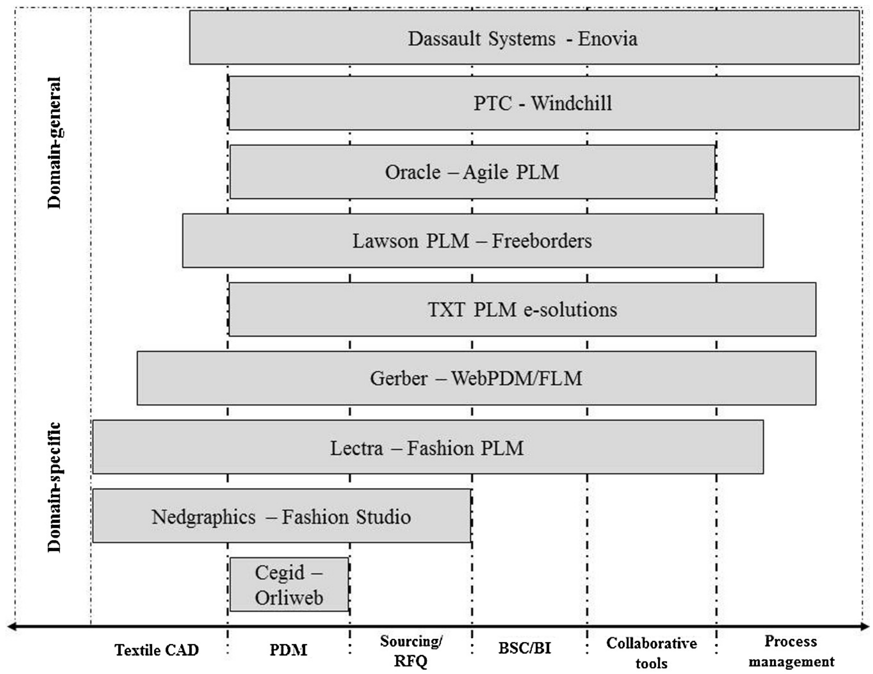

Fig. 3. Functionalities of various PLM systems.

presents a number of unique characteristics and requirements from the point of view of the design of tools to assist PLM, leading to the following questions: do the available tools truly address the needs of professionals in the textile industry, particularly in collaborative design teams? And what are the functions that are required in a collaborative tool for textile design?

To answer these questions, we have carried out a case study based on the principles outlined by Dul and Hak [19]. We will first present the context of our intervention, corresponding to what these authors call the stages of *problem finding* and *problem diagnosis* (Section 3.3); we will then describe an intervention consisting in the implementation of a new PLM environment at Devanlay, corresponding to the stages of *design of intervention*, *implementation*, and *evaluation* (Section 3.4). To answer the first research question noted above – focusing on user requirements analysis – we carried out a series of user interviews focusing on the kind of media used to support communication in collaborative work. To answer the second research question, the interview results served as a basis to define the functional specifications of a new tool, termed CoTeEn. Following a classical user-centred design methodology [20] we developed a mock-up of this collaborative tool which was subjected to user evaluation. In the stages of the project reported in this paper, we relied on questionnaires to assess the perception of various elements of the user interface by professionals in the company. Hence, our methodological proposal corresponds to the early stages of a user-centred design process, as defined by the ISO 9241-210 standard [21].

3. A case study in the textile industry

3.1. Context of the study and structure of the corporate group

The Devanlay group holds an exclusive license with the Lacoste clothing brand. Our industrial study took place mainly on the Paris site, where is located, in particular, the group's creation and marketing division. This office collaborates closely with a central development platform located in Troyes, France, which is in charge of product development. In the textile industry, the development cycle includes every stage from product launch up to withdrawal of the product from the market, but it is the stages of product definition and development which are the most demanding stages in terms of time and financial resources. Furthermore, the development cycle is unchanging, and corresponds to one season (there are two seasons per year). For example, Fig. 4 illustrates variations in stock size throughout the various stages of the product development cycle, in the case of the polo shirt – Lacoste's best-selling item. Many of the stages in this process can also be found in a classical product design process (needs analysis, conceptual design, implementation, etc.) as defined in [22,23]. Other stages are more specific, such as structuring the collection, or restocking. Restocking involves reorganizing the stock of needed items, but can also refer to reordering items from suppliers in the event of unexpectedly high sales. Production volumes are approximately 250,000 items per reference. One element that is specific to the design of a collection of clothing, for the purpose of selling these items to wholesale dealers or salespersons, is organizing a convention in order to present the items of the collection, to start the ordering phase, and to launch large-scale manufacturing of the items.

3.2. Stakes of PLM in product design

Designing items of clothing is a cyclical task, in the sense that starting up a collection begins with the analysis of the last collection. At the Devanlay company, the product development cycle currently lasts between 20 and 22 months depending on the collection, before the collection is discontinued. The product's time to market is approximately 13 months to store delivery. For the sake of comparison, the table below, adapted from [24], lists the time to market for the main textile brands. Over the past 25 years, the Lacoste collection has grown from 17 product references in 6 colours in 1985, to 1200 references in 8 colours in 2012. It stands to reason that the amount of technical data related to these items have grown accordingly (Table 1).

One of the priorities in implementing a PLM system in Devanlay is to foster creation and innovation in teams by reducing the administrative workload of operational teams. This aims to make it easier to implement a project and to improve the effectiveness of

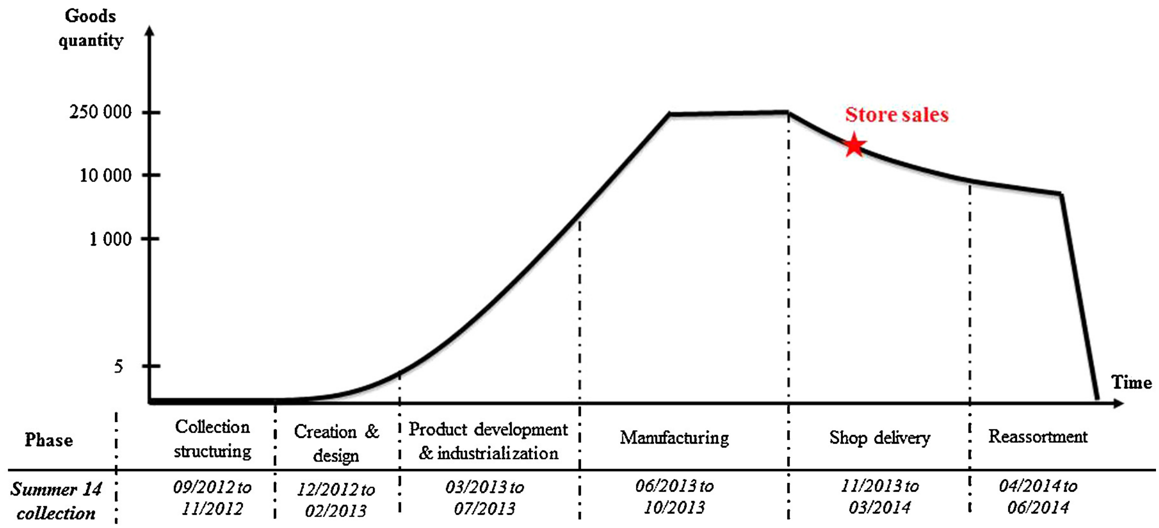

Fig. 4. Evolutions in stock for one item over the course of one season, example for a white polo shirt.

decision-making processes. This, in turn, will lead to reduced time to market and short manufacturing runs, making it possible to respond more efficiently to market needs. In this context, product development implies five main stages represented in Fig. 5:

- Analysing and structuring the collection: the goal of this stage is to define which items of clothing will be commercialized in the future collection, and in what quantities. This relies on analysing past sales, market needs, and emerging trends.
- Defining the product: the goal here is to define each product in the collection (one collection amounts to between 250 and 300 references) in terms of its colour/theme/material/cut characteristics. One source of intermediary data at this stage is the concept sketch file, which specifies all the information related to the product (detailed description, sizing, materials, supplies, etc.).
- Product design: the goal here is to design and to validate prototypes of items of clothing (a few dozen pieces for each reference) depending on the previously defined criteria of colour/theme/materials/cut.
- Product development aims to validate the definitive collection and to draft its final documents.
- Product industrialization: the goal is to produce the technical manufacturing file in order to launch manufacturing orders.

In order to support collaborative work and exchanges of technical data, the section below presents an experiment whose goal is to define the collaborative tools used by the company during product design. This allows us to provide adequate specifications for a PLM tool to support the textile design process.

3.3. Formulating the functional specifications of a collaborative PLM environment

User-Centred Design (UCD) of a collaborative PLM environment requires that decisions regarding system specifications be rooted in knowledge of end users' needs and activities. To produce such knowledge, we applied two different methods. We conducted a series of exploratory, open interviews with representatives of these end users, working in various departments of the company in order to better understand its workings (Section 3.3.1) and a questionnaire-based survey to learn about the tools used for collaboration in the company (Section 3.3.2). Analysing the media which workers used to communicate in their work allowed us to draw a list of functions required in the future PLM system (Section 3.3.3).

3.3.1. Exploratory interviews to understand collaborative work

Considering the complexity of the collaborative processes involved in the development of a textile product, as well as the sheer number of actors involved (about 300 people), characterizing the exchanges between these people is a crucial starting point in order to understand the collaborative activities which take place within the company. In order to provide the best possible specifications for a collaborative work environment, the first stage of our work aims to identify the main modes of communication used in the company.

In order to do this, we carried out a series of 18 interviews with a panel composed of professionals in clothing design at Devanlay,

Table 1
Examples of times to market in the textile industry [24].

Brand	Time to market
Devanlay (Lacoste)	13 months
Celio, AT, Bérénice	6 months
Zara	15 days

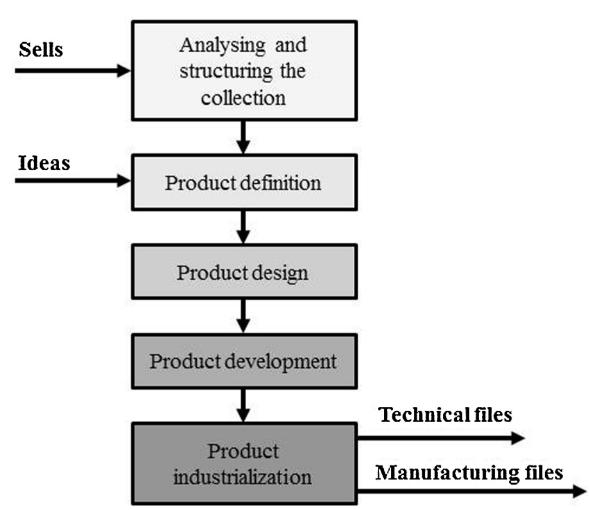

Fig. 5. Stages of a textile product design process, from [25].

Table 2
Departments involved in designing a new item of clothing, adapted from [24].

Department	Roles in the clothing design process
Style	Analysing trends Defining new patterns Creating new patterns Defining variants in pattern colours depending on the structure of the collection
Product design	Collecting market data Analysing sales from past seasons Structuring the collection in a collaboration with the style department Collaborate with the style department to create new patterns Produce documents for the collection
Information Systems	Selecting software programs suited to user needs Selecting database tools Implementing data storage space with tree structures intended to reflect the structure of the collection Ensuring quality and reliability of the transmitted information

including six persons from the "style" department, six from the "product design" department, and six from the "information systems" (IS) department. The latter do not take part directly in the development of a collection, but they play a crucial role in the implementation of new software tools that reflect the work practices of support teams.

Interviews were transcribed *verbatim* and subjected to content analysis [26]. This analysis focused on the functions of each department in the company, in order to understand the various tasks that might be carried out using the future PLM system. The roles of these departments are outlined in Table 2 below. The IS department is located at the crossroads between the company designers, based in Paris, and the engineers from product development, based in Troyes. Therefore, the persons from the IS department are in tune with what improvements could be made to their existing tools for collaboration. The three departments work in close collaboration throughout the early stages of the design process. One of the main goals of our interviews was to identify the forms of communication that were predominantly used within the company. Indeed, the fact that the company is located on two geographically separate sites makes exchanges between sites a crucial element of project success and completion. Analysing these communications, therefore, is a key part of the development of any new tool to support collaboration.

3.3.2. User surveys

Following the interview, the 18 participants took part in a questionnaire-based survey. This survey comprised two sections: (a) position occupied in the company and stages of the product lifecycle that their work focuses on; (b) media of communication used in everyday work. In addition, after filling in the survey, participants had the opportunity to discuss their responses with the experimenter is they wished to do so. We also used closed questions with Likert-type scales [27] to simplify data collection and analysis. This allowed us to collect precise data in a reasonable length of time (each survey lasted about 30 min) and fostered a genuine dialogue between the interviewer and interviewee, while preserving a framework that is tailored to the goals of the project. In our case, the questions focused on the types of communication tools used by the interviewees. Questions were grouped into four main topics: means of communication used, department involved in the communication, duration of use of the communication tool, and type of information transmitted.

Fig. 6 summarizes part of the results obtained in the surveys. Means of communication are classified depending on time (synchronous vs asynchronous communication) and space (colocation vs remote locations) [13].

Each circle represents one specific tool for communication. The diameter of the circle is proportional to the average number of occurrences of each item in the 18 surveys. For example, company employees use email in 50% of all communication situations, confirming the findings presented by Brown [28]. E-mail is the

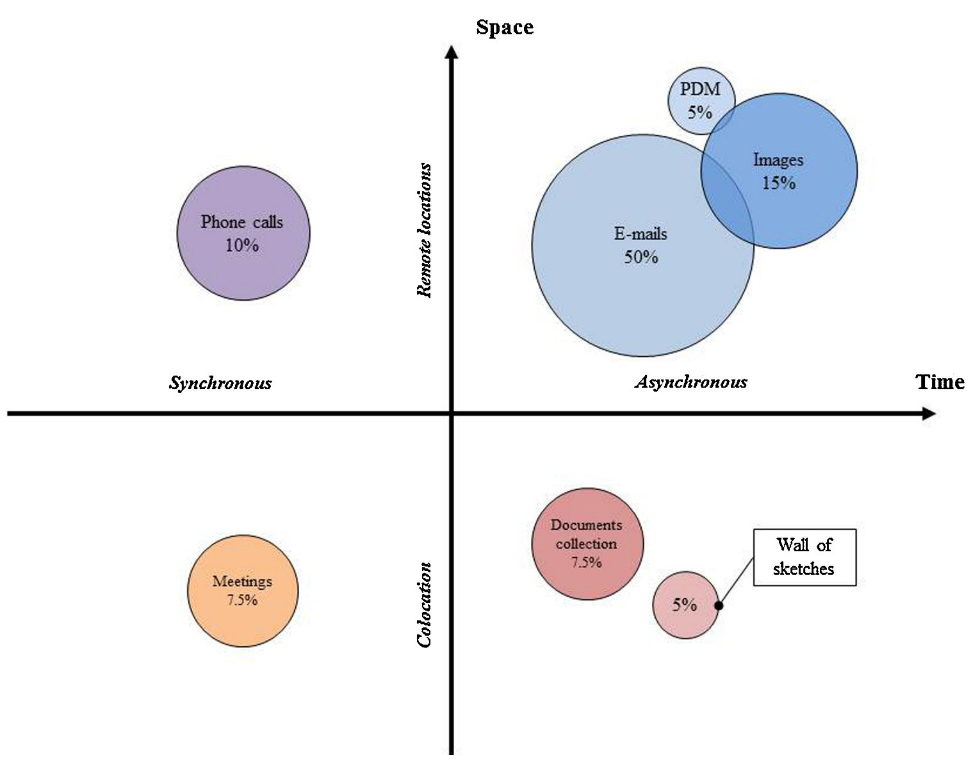

Fig. 6. Representation of the main collaboration tools used in Devanlay.

Process	Creative idea	Modelling	Prototyping	Dress rehearsal
Technical data	• Silhouette • Fashion flat • Fashion croquis	• Pattern drafts • Grading specifications • Bill of material	• Initial operating sequence	• Manufacturing specifications
Physical deliverable	Product concept file	Product file	Prototype	Collection

Fig. 7. The process of product data creation.

means of communication favoured by the participants in the product development process. One can deduce that a PLM tool will likely have to provide this means of communication, unless it is also provided through a dedicated email client.

Images are also frequently used as a means of communication (15% of cases). Indeed, in the early stages of the development process for the textile collection, IRs [29] of the product are almost exclusively graphical in nature (*e.g.* sketches, photos, outlines, etc. In particular, collection sketches have been identified as a key IR in the design process at Devanlay [24]. Communication then relies on annotations made directly on the sketches. Another example is the "wall of sketches", which groups by topic every element of the collection on a magnetized wall. This makes it possible to have an overall view of the harmony present in the collection.

Next, telephone calls have an important part in current communication practices at Devanlay (10% of situations). Telephone is often used as a complement to email in the case of highly technical discussions on the details of product design.

Finally, paper-based communication documents, sketch walls, and interactions with these graphical representations cannot currently be implemented in the digital design process. One final type of collaborative tool is the tools used for managing and communicating data related to the products themselves, also called Product Data Management (PDM) systems. These are used in 5% of communications over the course of the product's lifecycle. Some of the key functionalities of these PDM tools should therefore be introduced in our proposal for a collaborative environment to assist the early stages of the textile design process.

All these observations are important to help develop a prototype. We are interested in knowing not just which tools are used, but also what type of information is exchanged. Indeed, based on these results, it seems that the product's IRs hold a number of key information that should be provided by our prototype. In the section below, we list all the technical data which should be managed throughout the lifecycle process of an item of clothing, as evidenced by our experimentation at Devanlay.

3.3.3. *Listing the technical data required*

The interviews as well as the responses to the user survey allowed us to draw up a list of the data required by the end users of the PLM system as part of their everyday work. The first element of the design process that produces data on the product is the creative idea, which yields a number of overall characteristics for the product including the silhouette, the fashion flat, and the fashion sketch. This dataset constitutes the product concept file. Then, the product file includes pattern drafts, grading specifications and bill of material. This marks the end of the stages of product design. Later stages focus on the physical design of the product, starting with the prototyping stage that sets the data for the initial operating sequence. The last stage focuses on the production line, where the collection itself is generated through a process of dress rehearsal.

Fig. 7 illustrates the successive stages in referencing technical data and physical deliverables.

In addition to listing which collaborative tools were favoured in the company, our analysis thus allowed us to classify the types of IRs used. These specifications will be useful to the design and test of a collaborative platform.

3.4. *Deployment and testing of a collaborative platform suited to the requirements of Devanlay: CoTeEn*

We created the mock-up of a collaborative tool using Publisher in order to validate its main functionalities. The functional architecture of this tool, named CoTeEn for "**Co**llaborative **Te**xtile **En**vironment", is presented in Fig. 8.

Within this tool's functionalities, are included the main communication tools defined in Fig. 6. In particular, the CoTeEn tool allows direct access to e-mail (50% of the instances of collaboration) and also allows access to the various IRs of the product by using the "search for reference" thumbnail (15% of cases of collaboration).

Finally, we have developed an entire module dedicated to sketch-based collaboration via annotations, since this was identified as a key IRs in the design process at Devanlay [24]. This module makes it possible for many people to collaborate and annotate product sketches in a synchronous or asynchronous manner. This tool makes it possible to centralize all the remarks related to a particular model, whether these remarks come from the style department, production department, or others.

The CoTeEn tool prototype, which serves to support a collaborative environment in the early stages of design in the textile industry, is represented in Fig. 9. It was subjected to numerous tests involving five experts in the company. Following these tests, the reactions of the experts were collected using a two-page questionnaire. This questionnaire is structured according to five key topics related to the functionalities that are expected from this tool:

- The startup screen: are the icons clear? Does the tool make the users want to use it? etc.
- The design of the Human–Computer Interface (HCI): is the environment clearly presented? Is it consistent with the company identity? Are the contents well articulated with one another? Is the navigation intuitive? etc.

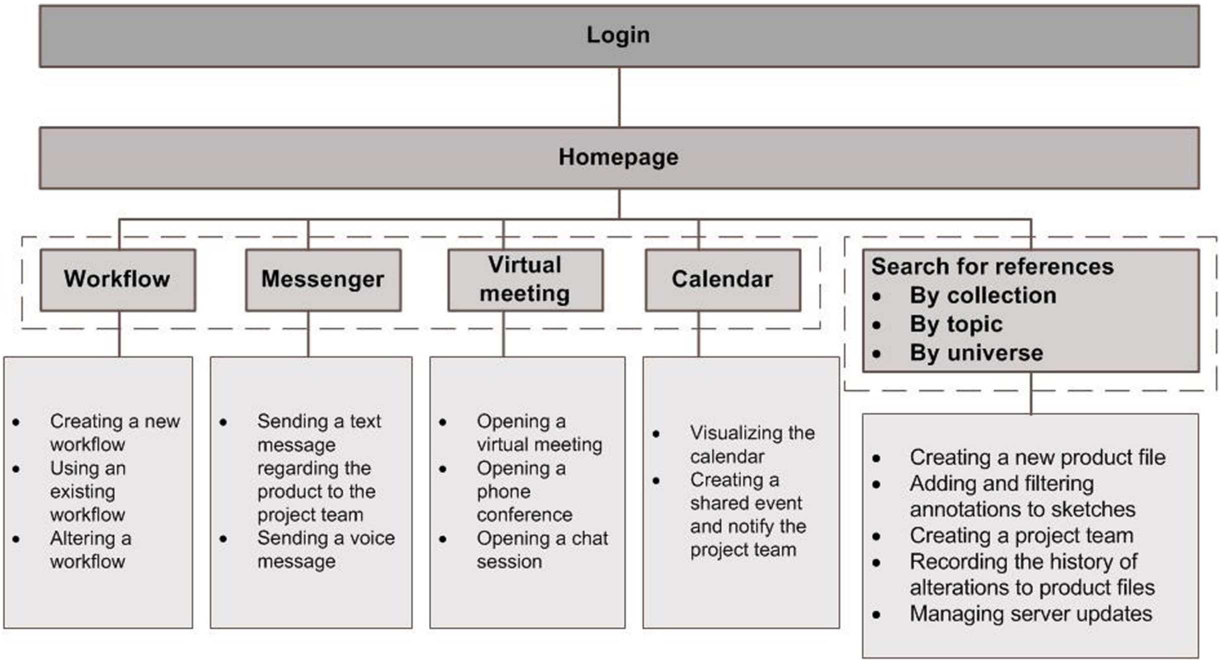

Fig. 8. Structure of the pages in the functional mock-up of CoTeEn.

- Contents: does the tool offer new, interesting functionalities? Are there any functions lacking? Are the available options representative of my everyday work? Can the contents be understood without any additional explanation? Are the contents logically related? Etc.
- Communication: do the pages encourage you to interact with them?
- Overall: do you believe that this kind of collaborative environment for the early stages of design is realistic?

Users were requested to respond using a five-point Likert scale, ranging from "not at all" or "totally ill-suited" to "absolutely" or "excellent". Likert scales are more intuitive than Osgood's semantic differential scale [30]. A semantic analysis scale is in the form of a list of adjectives, or items, that are grouped in pairs and lined up, or separated by an odd number of boxes (usually 5 or 7). Allowing participants to position their judgement on each line as a point located between these two extremities. The central point corresponds to a neutral judgement. Although the meaning of the adjective is more precise in a semantic differential scale, the participant may feel uneasy during the evaluation. The reason why the adjectives are more precise is the presence of an antonym, which allows disambiguating the meaning of the adjective used.

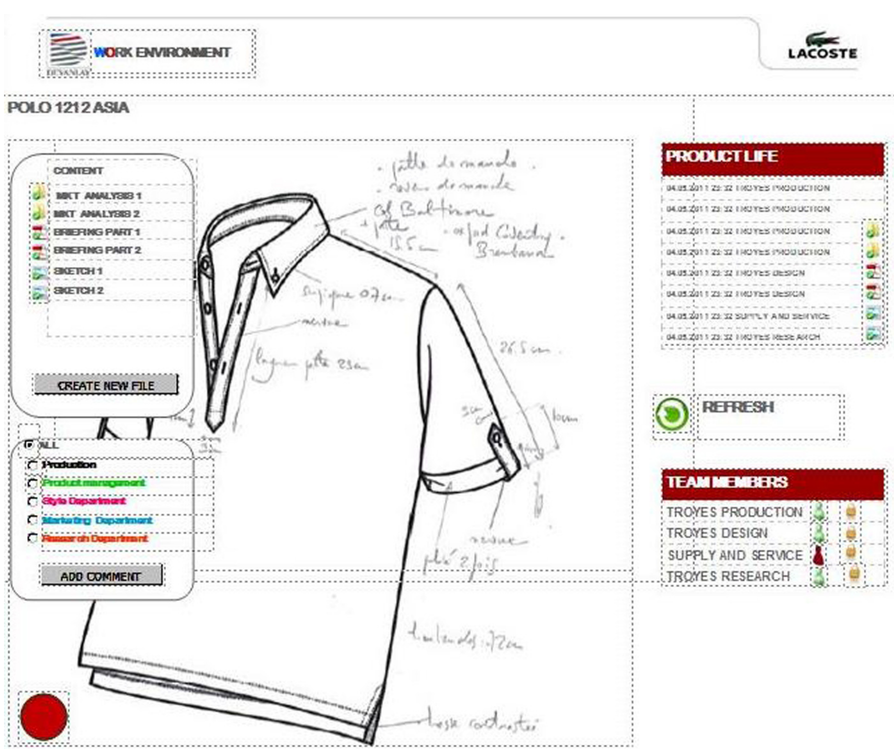

Fig. 9. CoTeEn's sketch-based annotation tool.

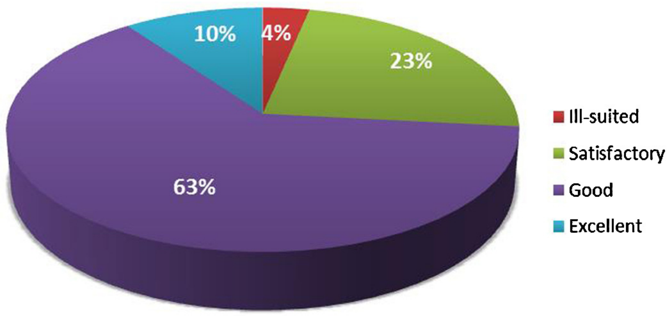

Fig. 10. Results of user tests related to the contents of the CoTeEn tool.

For example, the adjective "intuitive" has a different meaning depending on if it is associated with the adjective "rational" or with the expression "requires learning". However, the rating scale itself may be more difficult to fill in because of the fact that the rating is less intuitive.

For this reason, we have chosen to use Likert-scale [27] type ratings. However, one must point out that the expression Likert scale is ill-suited, since such scales do not use antonymous adjectives to specify their meaning. When choosing the items, the respondents to the questionnaire must be clearly identified. This makes it possible to adjust the tone and formulation of the questions and to use an appropriate vocabulary – one should not use technical terms when addressing newcomers.

Results concerning contents and communication are illustrated in Fig. 10. They show that the users subscribe completely to our proposal. The questions posed in this section of the questionnaire were: the site offers interesting new options that concern my work; there are options and functions missing; the options offered by the work environment are represented in my real work; contents are understandable without any further explanations; the contents are logically linked; contents motivated me to act (complete files, add documents etc.).

The most important criterion to us is obviously the contents proposed for the platform. These require, in order to be relevant, from designers to apprehend the complete design process. It emerges that the participants we have involved in the process appreciate this solution proposal, suggesting that the functional mock-up of our collaborative environment does indeed respond to the needs of users at Devanlay. Our work of formalizing this process has a lot to do with this result. Indeed, it allowed us to better understand the stakes of design and the contents that were necessary for the development of a product.

To answer our research questions, we demonstrated thanks to the series of user interviews that the available PLM tools don't truly address the needs of professionals in the textile industry. Then, using the basis of the interview and our state of the art, we have shown that the required functions in a collaborative tool for textile design are: messenger calendar and email functionalities, virtual meeting, workflow management, access to the various IRs and sketch-based annotation tool.

We will now propose a conclusion regarding the generalizability of these results and the process used in this case study.

4. Conclusions and prospects for future work

In this paper, we highlighted the key stakes in the implementation of a new PLM tool. Following a comprehensive review of existing PLM solutions and of the suitability of their functions to the world of textile design, we presented a case study of a company where we contributed to the design of a new PLM system to support design activities. To do this, we mapped and quantified the collaborative exchanges involved in the design of a textile product in the Devanlay company, based on a series of open interviews and on a survey carried out with end users working within the company. This allowed us to identify the product data that was required by these end users to carry out their design work, as part of a contribution to the early stages of the design process for this collaborative PLM system. The emergence of PLM tools, following increasing competition between businesses requires a fine-grained analysis of user needs, in terms of collaboration and exchanges of technical data before designing and deploying the system. The field work reported here allowed us to specify some useful solutions to implement a PLM solution. The method used for collecting and analyzing user needs, which are specific to the textile industry, can be replicated – and is necessary for defining a collaborative work environment that is optimally suited to user needs. Our approach, which is suited to the context of our intervention, makes it possible to deploy and test a tailored PLM solution, based on feedback from end users.

References

[1] C. Pezeshki, R.T. Frame, B. Humann, Preparing undergraduate mechanical engineering students for the global marketplace-new demands and requirements, in: ASEE Annual Conference Proceedings, Salt Lake City, USA, (2004), pp. 321–332.
[2] N. Maranzana, F. Segonds, F. Lesage, J. Nelson, Collaborative design tools: a comparison between free software and PLM solutions in engineering education, in: L. Rivest, A. Bouras, B. Louhichi (Eds.), Product Lifecycle Management. Towards Knowledge-Rich Enterprises, vol. 388, Springer, Berlin, Heidelberg, 2012, pp. 547–558.
[3] S. Sharifi, K.S. Pawar, Product Development Strategies for Agility. Agile Manufacturing: The 21st Century Competitive Strategy, 2001, 175–197.
[4] B. Prasad, Concurrent Engineering Fundamentals: Integrated Product and Process Organization, vol. 1, Prentice-Hall, London, 1996.
[5] G. Sohlenius, Concurrent Engineering, Ann. CIRP 41 (1992) 645–655.
[6] R.I. Winner, J.P. Pennell, H.E. Bertrand, M.M. Slusarczuk, The Role of Concurrent Engineering in Weapons System Acquisition, I.R. R-338, Institute for Defense Analyses, Alexandria, VA, 1988.
[7] M. Garetti, S. Terzi, N. Bertacci, M. Brianza, Organisational change and knowledge management in PLM implementation, Int. J. Prod. Lifecycle Manage. 1 (1) (2005) 43.
[8] G. Schuh, H. Rozenfeld, D. Assmusa, E. Zancul, Process oriented framework to support PLM next term implementation, Comput. Ind. 59 (2–3) (2008) 210–218.
[9] K. Amann, Product Lifecycle Management: Empowering the Future of Business, CIMdata, Inc., 2002.
[10] J. Le Duigou, A. Bernard, N. Perry, Framework for Product Lifecycle Management in-tegration in small and medium enterprises networks, Comput-Aided Des. Appl. 8 (4) (2011) 531–544.
[11] S. Zina, M. Lombard, L. Lossent, C. Henriot, Generic modeling and configuration management in product lifecycle management, Int. J. Comput. Commun. Control 1 (4) (2006) 126–138.
[12] ISO 10007:2003, Quality Management Systems – Guidelines for Configuration Management, 2003.
[13] R. Johansen, Groupware Computer Support for Business Teams, The Free Press, New York, 1988.
[14] S. El Kadiri, P. Pernelle, M. Delattre, A. Bouras, Current situation of PLM systems in SME/SMI: survey's results and analysis, in: 6th International Conference on Product Lifecycle Management, Bath, UK, (2009), pp. 436–446.
[15] Y.-J. Liu, D.-L. Zhang, M.M.-F. Yuen, A survey on CAD methods in 3D garment design, Comput. Ind. 61 (2010) 576–593.
[16] P. Volino, F. Cordier, N. Magnenat-Thalmann, From early virtual garment simulation to interactive fashion design, CAD Comput. Aided Des. 37 (6) (2005) 593–608.
[17] M. Maguire, Methods to support human-centered design, Int. J. Hum.-Comput. Stud. 55 (2001) 587–634.
[18] A. Holzinger, Usability engineering for software developers, CACM 48 (1) (2005) 71–74.
[19] J. Dul, T. Hak, Case Study Methodology in Business Research, Elsevier, Amsterdam, 2008.
[20] J. Nielsen, Usability Engineering, Harcourt Science and Technology Company, San Diego, 1993.
[21] ISO 9241-210:2010, Ergonomics of Human–System Interaction, 2010.
[22] T.J. Howard, S.J. Culley, E. Dekoninck, Describing the creative design process by the integration of engineering design and cognitive psychology literature, Des. Stud. 29 (2) (2008) 160–180.
[23] G. Pahl, W. Beitz, Engineering Design – A Systematic Approach, The Design Council/Springer, London/Berlin, 1984.
[24] F. Segonds, Contribution to the Integration of a Collaborative Design Environment in the Early Stages of Design, (Ph.D. thesis), Arts et Metiers ParisTech, 2011p. 245.
[25] G. Gaillard, PLM. Expertise in the Clothing and Retail Sectors: the Devanlay and Lacoste Case Study, Technical Presentation, Devanlay, 2012.
[26] K. Krippendorff, in: T. Oaks (Ed.), Content Analysis. An Introduction to Its Methodology, 2nd ed., SAGE Publications, 2004.
[27] R. Likert, A technique for the measurement of attitudes, Arch. Psychol. 140 (1932) 1–55.

[28] J. Brown, The Product Lifecycle Collaboration Benchmark Report – The Product Profitability X-Factor, Aberdeen Group, USA, 2006.
[29] C. Bouchard, R. Camous, A. Aoussat, Nature and role of intermediate representations (IR) in the design process: case studies in car design, Int. J. Veh. Des. 38 (1) (2005) 1.
[30] C.E. Osgood, C.J. Suci, G.H. Tannenbaum, The Measurement of Meaning, University of Illinois Press, Urbana, 1957.

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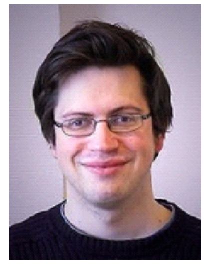

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